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Palestine Polytechnic University Third International Conference on Energy and Environmental Protection in Sustainable Development (ICEEP III), October 9-10, 2013, Hebron, West bank, State of Palestine

Paper Code. No. ENE153

Fuel Quality Implications on Combustion Engines in the West Bank Area of Palestine

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ABSTRACT

Demand on automotive fuel has been growing in the last two decades in Palestinian areas due to the expansion of urban areas from one side and the emerging of the Palestinian Authority (PA), which has established institutions and drafted legislations that encouraged open market with the assistances provided by the donor countries. Nearly, more than 30% of ground private and public transportation means are considered new. Local automotive dealers and agencies are claiming that engine and exhaust systems' failure are due to the properties of the imported fuel; mainly diesel and gasoline (95). With the absence of regular monitoring on the imported fuel, an investigation is carried out to identify the relevant automotive fuel properties and comparing them with the standard index. The investigation is also carried out on the comparison of imported fuel with similar fuel sold in fuel stations in the occupied Jerusalem. This investigation has been carried out using sample collection and testing in accordance to ATSM relevant series. Results showed that nearly all collected samples agree to some extents with the standards identified by EURO 4, with the exception of diesel fuel samples' heat content properties that showed considerable deviation of all samples from the international index.

1 INTRODUCTION

The West Bank part of Palestine has an abnormal political situation that affects transportation sector direct as well as indirectly. The accessibility to proper road infrastructure is always limited and controlled by the occupation. In addition, roads infrastructure within most of the West Bank areas have not been developed to cope with the steady growth in number of vehicles owned by Palestinians. In 1993 there were about 60,000 registered vehicles that doubled in 2005 and steadily grown to reach about 200,000 registered vehicles by the end of 2011 [1].

The consequence is the growth in automotive fuel consumptions which is imported mainly from the occupation in frameworks of agreements monopolized by the occupation in terms of the prices. In that sense, the Palestinian per capita GDP, which is one-tenth compared to that of the occupation, has to pay same price for fuel. The fuel imparted by the PA comes with occupation certificate bounded by the EURO 4 standards, which is also approved by the PA. The standards identify the minimum standards properties' values for the imported fuel. However, although such standards are the regulatory background requirements that govern the imported fuel, but the PA's

General Directorate of Petroleum does not implementing any control scheme through which fuel samples could be collected randomly from the fuel stations and tested for compliment with the EURO 4 standards. This is a serious issues that has been in debate by the auto dealers and agencies that grown in the last ten years because of the growing demands on new brand vehicles for private and public transportation sectors. Part of the claims made by the automotive agencies were focusing on the possible low quality of the sold automotive fuel that results in growing automotive engine and exhaust system frailer.

The work presented in this paper is a response to such claims as it focuses on testing the quality of the fuel by identifying as many known properties as possible and comparing them to the internationally recognized standards. And in order to be more certain, comparison is also done with the same fuel sold in the occupied Jerusalem where fuels are controlled and monitored by the occupation. Properties identified in accordance to their relevancy to combustion. These are the cetane index, octane rating, distillation, viscosity, density, calorific value, sulphur content, recovery and water content. All mentioned properties may have direct or indirect effects on combustion process inside the combustion chambers. Combustion efficiency might be affected due to the change in delay period, flame temperature, heat rate or mixture strength.

1.1 Fuel properties

1.1.1 Cetane number: or CN is a measure of the ignition quality of diesel fuel based on the ignition delay in an engine, the higher the cetane rating; the shorter the ignition delay and the better the ignition quality [2,3]. Many investigations on CN were performed during the resent decades. One of the latest researches concerning CN [4] was about the effect of improving cetane number of diesel fuel, on the performance and emissions of a multi cylinder diesel engine under variable operating conditions. 4 kinds of diesel fuel with different cetane numbers were used, the conventional diesel fuel (CN=48.5) was used as baseline , its cetane number was improved in 3 different rates (CN=50, 52, and 55). They found that CN strongly affects the ignition delay by shortening it, this will lead to earlier combustion phasing. The bsfc was reduced by 5.5%, the brake thermal efficiency was increased by 9%, while the brake power was increased by 5.6%. Engine emissions were also reduced with increasing CN. NOx emissions were reduced by 6%, CO was reduced by 30.7%, HC and noise were reduced as well, CO_2 was increased with increasing CN.

1.1.2 Sulphur content: naturally found in crude oil. If the sulphur is not removed during the refining process it will contaminate vehicle fuel, it has a significant impact on vehicle emissions by reducing the efficiency of catalyst. Markets follow EURO 4 limits sulphur content in gasoline, it shouldn’t exceed 30 ppm. Sulphur in diesel fuel causes combustion chamber deposits, exhaust system corrosion, and wear on pistons, rings and cylinders, particularly at low water-jacket temperatures. Sulphur shouldn’t reach 10 ppm by mass in the diesel fuel according to EURO 4 [5].

1.1.3 Octane number: represents the ability to resist auto-ignition of gasoline during the compression stroke of the combustion. The higher the octane number the more auto-ignition is resistive. The measurement of octane number is done when comparing the fuel with isooctane which has octane number of 100 and n-heptane which has octane number of 0, so the fuel octane number is determined according to its behavior between these two compounds [6]. In recent years, many researchers investigated the effect of octane number on engine performance and emissions, since it has a direct influence on engine detonation. Cenk Sayin [7] investigated the impact of varying spark timing at different octane numbers on the performance and emission characteristics in gasoline engine, he used 3 different octane ratings, he found that increasing octane number will improve brake specific fuel consumption and thermal efficiency. As the maximum pressure and temperature are increased, this will reduce CO and HC, but it will increase NOx.

1.1.4 Density and Viscosity: variations in fuel density and viscosity result in variations in engine power and emissions and fuel consumption. In order to optimize engine performance and tailpipe emissions, both minimum and maximum density limits must be defined in fairly narrow range, for gasoline the density should be between 715-770 kg/m^3, while the range for diesel it should be in the range of 820-840 kg/m^3. The viscosity is important in diesel oil and its range should be 2-4 mm^2/s [5]. Emission testing has demonstrated that reduced density will reduce PM and NOx emissions from heavy-duty vehicles but fuel consumption will increase and power will reduce. High viscosity can reduce fuel flow rates, resulting in inadequate fueling, while low viscosity will increase leaking from pumping elements, so it is important to minimize the range between minimum and maximum viscosity limits to allow optimization of engine performance [5].

1.1.5 Fuel heating value, the higher heating value (HHV): or calorific value of a substance, usually a fuel, is the amount of heat released during the combustion of a specified amount of it. The energy value is a characteristic for each substance. It is measured in units of energy per unit of the substance, usually mass, such as: kJ/kg, kJ/mol, kcal/kg, Btu/lb. Heating value is commonly determined by use of an oxygen bomb calorimeter. The quantity known as higher heating value (HHV) or gross calorific value (GCV) is determined by bringing all the products of combustion back to the original pre-combustion temperature, and in particular condensing any vapor produced. Such measurements often use a standard temperature of 25°C. This is the same as the thermodynamic heat of combustion since the enthalpy change for the reaction assumes a common temperature of the compounds before and after combustion, in which case the water produced by combustion is liquid. The HHV takes into account the latent heat of vaporization of water in the combustion products, and is useful in calculating heating values for fuels where condensation of the reaction products is practical. This means that the HHV assumes all water content is in liquid state in product of combustion and that heat above 150 °C can be put to use. Another term used to describe the heating value is the lower heating or net calorific value (LHV or NCV), which can be determined by subtracting the heat of vaporization of the water vapor from the higher heating value. This treats any water formed as a vapor. The energy required to vaporize the water therefore is not realized as heat.

1.1.6 Moisture or water content: water is always present in some degrees in the automotive fuel, which may be a result of condensation when temperatures rise and fall by more than 7 degrees, or by leaky storage tanks or by other means. Water presence in fuel may cause stalling, carburettor icing, fuel line freezing and corrosion in the fuel tank and lines, and injector and engine damage.

2 METHODOLOGY

In order to assess automotive fuel properties, benzene and diesel, a number of fuel stations were identified in Ramallah (controlled by the Palestinian Authority jurisdiction) and in Jerusalem (controlled by occupation legislations). The choice was to choose fuel stations in both traffic-busy area and low traffic area, in the centre of the city and in the city outskirt. By doing so, we could check different conditions related to daily sales and its impact on the quality of fuel expressed in the properties that are possible to test. Nine stations identified; five in the Ramallah district and the rest four are located in Jerusalem. The stations were given the code as in Table 1 below.

Table 1: Identified Stations and sampling codes

City	Station	Fuel Sample code
Jerusalem	Jerusalem 1	Gasoline (JS01), Diesel (JD01)
	Jerusalem 2	Gasoline (JS02), Diesel (JD02)
	Jerusalem 3	Gasoline (JS03), Diesel (JD03)
	Jerusalem 4	Gasoline (JS04), Diesel (JD04)
Ramallah	Ramallah 1	Gasoline (RS01), Diesel (RD01)
	Ramallah 2	Gasoline (RS02), Diesel (RD02)
	Ramallah 3	Gasoline (RS03), Diesel (RD03)
	Ramallah 4	Gasoline (RS04), Diesel (RD04)
	Ramallah 5	Gasoline (RS05), Diesel (RD05)

Gasoline is a mixture of flammable volatile liquid hydrocarbons resulted from petroleum refinement process. These hydrocarbons are paraffin, olefins and aromatics which are composed of 4-12 carbon atoms per one molecule and have a boiling point below 200°C [5]. Testing is limited to unleaded gasoline 95 as it is mostly used in gasoline mobile engines. The diesel fuel is acquired from petroleum, where it is distillate from crude oil in a percentage of 22.4% [8] this type of diesel is called petro-diesel. Both fuels are widely used for small passenger cars, public transportation, and heavy transportations.

Sampling was accomplished by collecting two fuel samples from each designated fuel pump in each fuel station. The size of the sample was set to be one litre.

In order to test the properties of samples collected, potential test tools available were assessed and the results showed that potential testing facilities exists in both the Palestine Polytechnic, and in Birzeit Universities. Testing of samples were performed in accordance to the International Standards ASTM; formerly known as the American Society for Testing and Materials. Table 2 shows the properties being identified for testing and the corresponding ASTM test procedure adopted.

Table 2: Tested properties and the corresponding ASTM standard testing procedure

Tested property	ASTM procedure	
	Gasoline	Diesel
Octane number	ASTM method D2700	
Recovery or volatility	ASTM D86	
Viscosity	ASTM D4052	
Density	ASTM D4052	
Calorific value	ASTM E711	
Moisture content	ASTM D6304	
Cetane number	ASTM D61e3	
Cetane index	ASTM D4737	
Flash point	ASTM D93	

Recovery of fuel sample expressed as volatility was done by a distillation test. It is worth mentioning that the recovery percentage for both gasoline and diesel has to be more than 98% of the original volume, which means that 98% of the substance unit volume is volatile. Testing of the calorific values were done using the oxygen bomb calorimeter based on its four repeated calibration tests with benzoic acids.

3 RESULTS

Cetane number was measured for each sample; all samples showed accepted values above the minimum, as shown in Figure 1, some variations were noticed in Jerusalem stations, JD02 was just above the minimum.

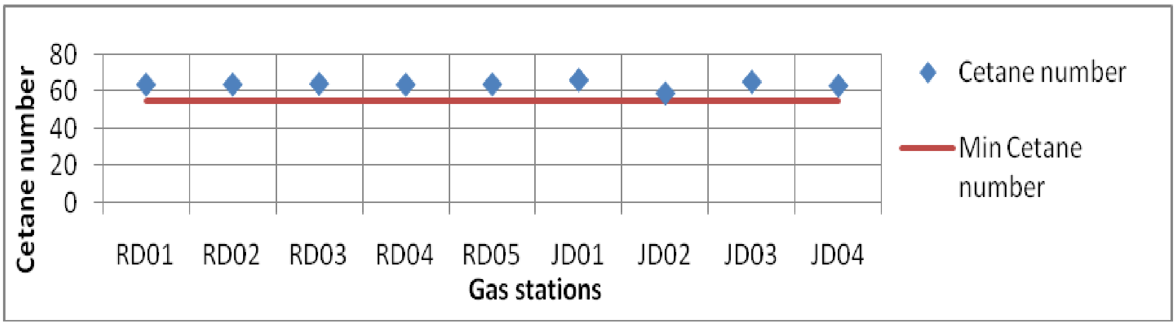

Figure 1: CN values in each gas station compared with the minimum permitted CN

In Figure 2, octane rating which is the average of research and motor octane numbers; (RON+MON)/2. The minimum value according to category 4 in the worldwide fuel charter is 87.5, all samples showed values above the minimum, most of them were about 92 which is high enough to be accepted.

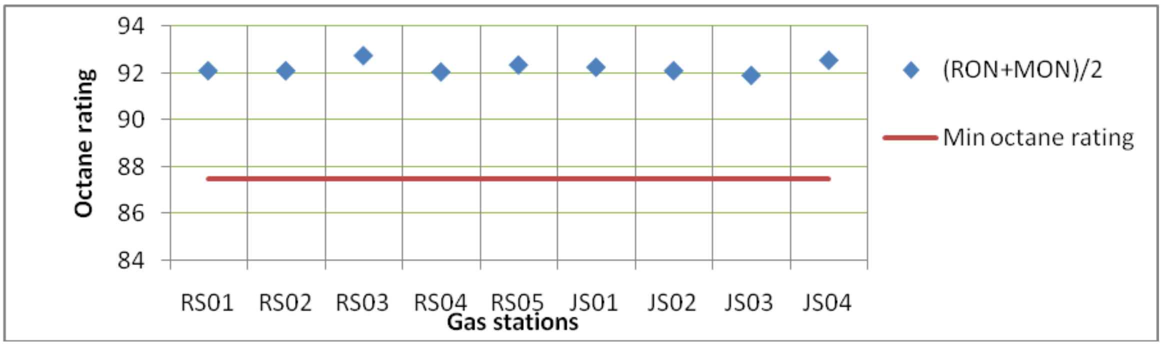

Figure 2: Octane rating in each gas station compared with the minimum permitted value.

Figures 3 and 4 shows the densities of gasoline and diesel, they are within the permitted range according to EURO 4 specifications.

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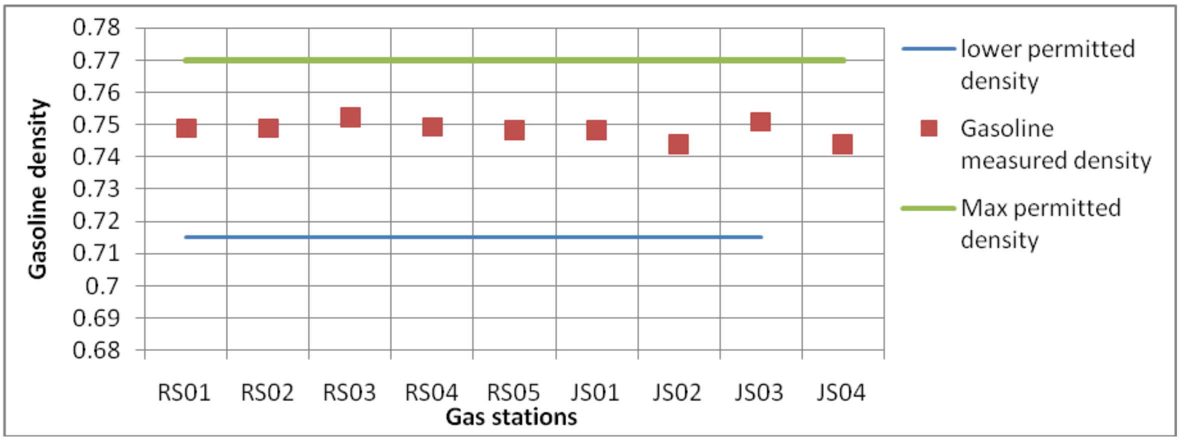

Figure 3: Measured gasoline densities for various gas stations.

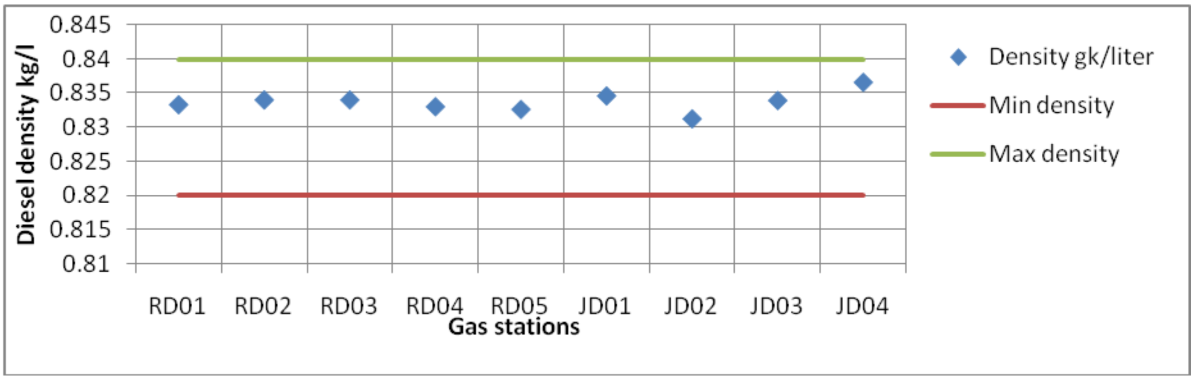

Figure 4: Diesel density for various gas stations.

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Diesel viscosity in centistocks is presented in Figure 5, all samples showed that the viscosity values were within the permitted range.

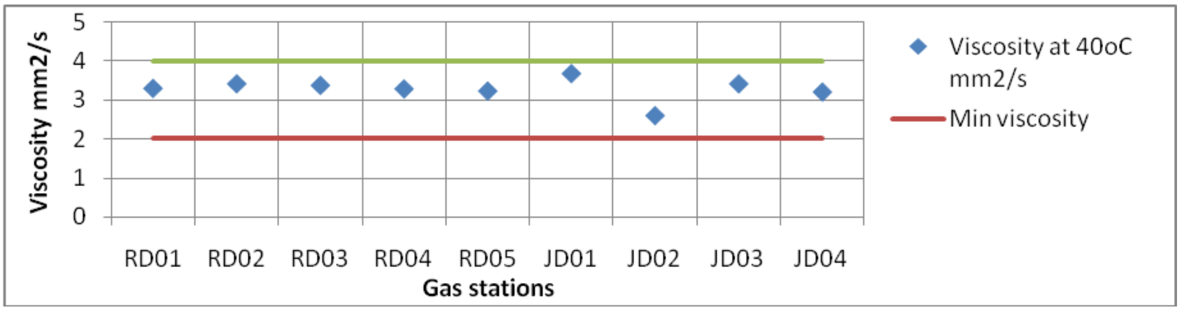

Figure 5: Diesel viscosity for various gas stations

Sulphur content is presented in Figure 6, all samples showed that sulphur is content is below the minimum permitted values for all samples.

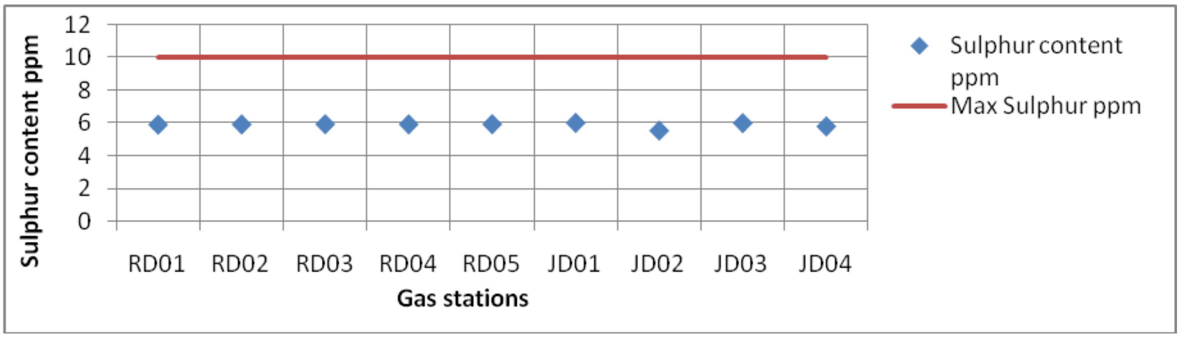

Figure 6: Sulphur content in the various gas stations.

Testing using oxygen bumb calorimeter for all fuel samples brough different results. Index reference range values for HHV for both diesl and gasoline 95 were also taken and used for comparision as in Figures 7 and 8.

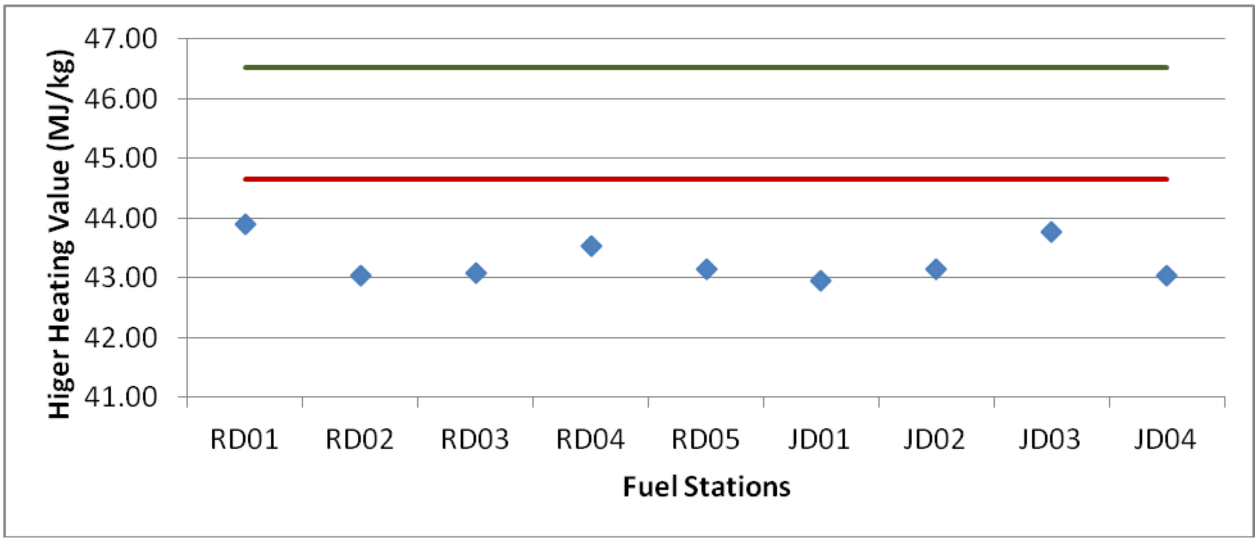

Figure 7**:** HHV for collected diesel fuel samples compared to standards range

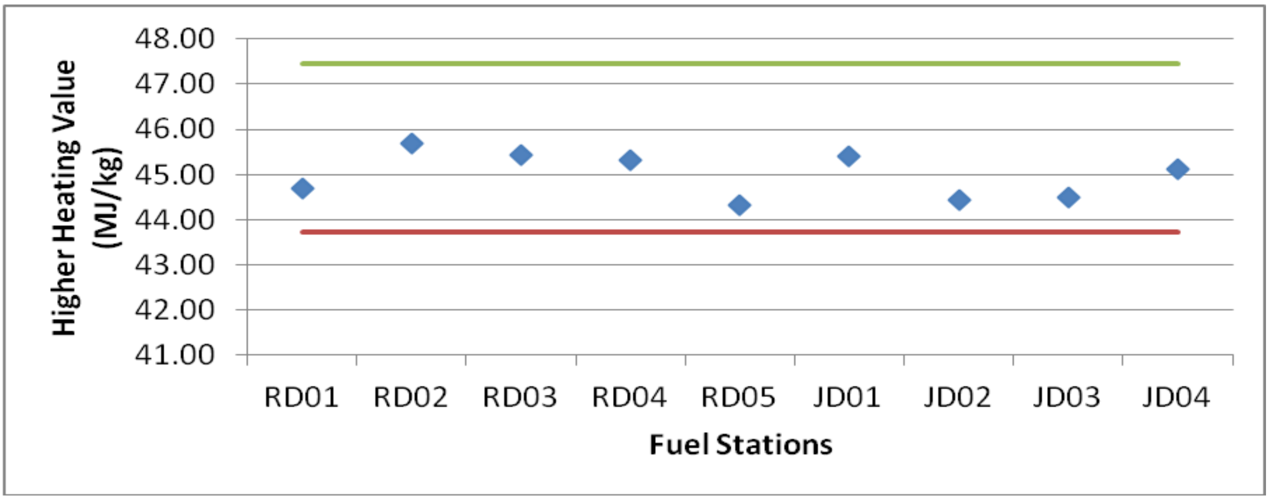

Figure 8**:** HHV for collected gasoline fuel samples compared to standards range

In comparison with standards range of HHV, diesel samples tested showed an deviation of 5% below the lower limit of the standards HHV for all samples. The lower range value of the HHV of gasoline accommodated all sample values that are shown to be in the range with an acceptable average deviation to the average standards HHV of 1%.

With regard to water content, all samples showed that water content is well below the upper limit of 200 mg/kg identified in EURO 4 (see Figure 9 below).

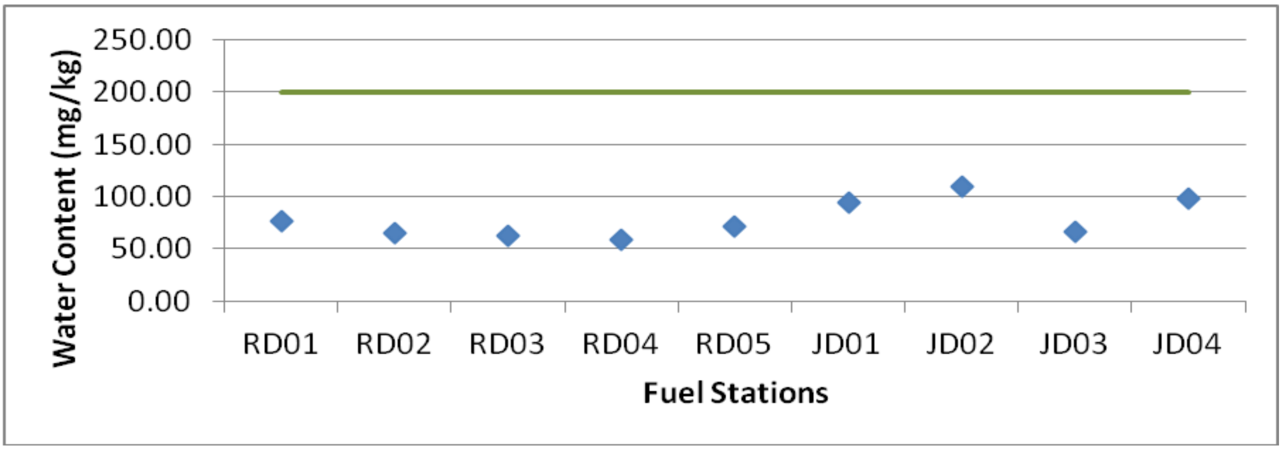

Figure 9: Water content test results for diesel fuel samples and the upper standdards limit

4 CONCLUSION

The research conducted revealed that fuel sold in the West Bank area agree well in its properties with that sold in the occupied Jerusalem. In addition, fuel properties identified and tested are found falling in ranges of the international standards values identified by EURO 4. In light of this findings, the possibility of engine malfunction form the fuel properties is not well identified. There is however, one major deviation concerning the heating values of the diesel fuel when compared to index value with a deviation of – 4%. It is not clear that such deviation may affect the combustion or the exhaust system and hence may be considered as leading to system malfunction.

5 ACKNOWLEDGEMENT

The authors would like to acknowledge the assistant provided by Ahmad Jaradat, Mohammad Samara an Majdi Bannoura of Birzeit University, the Birzeit University laboratories and the Palestine Polytechnic laboratories.

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